International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 3, Issue 9, pp 55-73, September - 2019

Toward an Improved Performance Analysis Model for Adapting the Capabilities of Routing Protocols in MANET

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***Abstract* - This work, aims to present a novel framework for performance analysis and adoption of MANET routing protocols. The framework consists of three integrated main phases; the first phase starts by investigating the performance of all MANET routing protocols' categories. The second phase uses the outcome of the first phase to build an evaluation dataset ready for applying machine learning techniques to predicate the performance behavior of each routing protocol. The last phase allows the adoption of optimal MANET protocol within different network scenarios and considering performance needs. The proposed model seeks to understand MANET routing protocols through literature. In addition, determine the list of protocols categories to be investigating. Then analyze selected protocols' performance in different network scenarios. This to build a dataset used for estimating and predicting routing protocols performance within different network scenarios. To allow the predicate of optimal protocol features based on network properties and settings.**

Keywords: Mobile ad hoc networks, Routing protocol, Performance metrics.

I. INTRODUCTION

The Mobile Ad hoc Networks (MANET) consists of a group of wireless mobile nodes (laptop, Mobile phone, PDA, MP3 player etc..) that are used as a transmitter, router or receive over the network. MANET is homogeneous network when the network nodes have the same platforms, structure and capabilities and heterogeneous when otherwise. In MANETs, nodes are free in moving which provide dynamic topology, self-healing and fault resilience, as shown in figure (1).

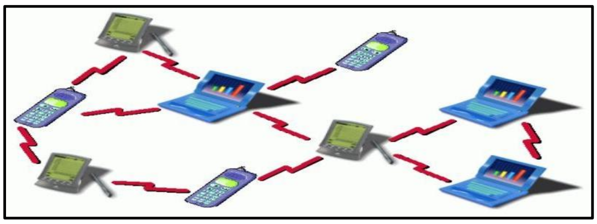

Figure 1: A Simple of Ad-Hoc Network

However, nodes have limited CPU capacity, battery power, storage capacity, and bandwidth. Therefore, the power usage must be reduced to increase the transmitter rate of the network nodes. In MANETs, Routing protocols define the governing rules and parameters that are used to forward the packets over the network among the communicating nodes. Routing protocols discover routes among the nodes using routing algorithms. The routing protocol has two main roles, the first role is selection of routes for the source and destination nodes and delivery the messages to the correct destination. The second role is using a suitable protocol to propagate the data packets.

Recently, there are many routing protocols algorithms suggested to overcome MANETs challenges such as dynamic topology changes, link failure, limited bandwidth, limited power, routing power consumption.

In this research, an intensive performance analysis among a wide verity of MANETs routing protocols is taking place. Performance metrics considered are Average end to end delay (E2ED), Packet Delivery Ratio (PDR), Throughput (THP) and Routing Overhead (RO). In addition, machine learning model is used to build a new testing dataset allowing to perform a comparative analysis and classification between selected MANET routing protocols.

In this research, an intensive performance analysis and investigation of MANET routing protocols are conducted. Two main categories of MANET protocols are considering including topology based routing protocols and position based routing protocols.

The topology based routing protocols divided into three categories, which are proactive, reactive, and hybrid routing protocols. were the routing protocols being selected from topology based are DSDV- proactive - distance vector routing protocol, OLSR- proactive - link state routing protocol, (AODV, DSR) - reactive - uni-path routing protocol, TORA - reactive - multi-path routing protocol and ZRP - hybrid routing protocol. In addition GPSR from position-based routing protocols.

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In this research the main scope is:

1) How to build a performance evaluation dataset representing all categories of MANET routing protocols.
2) How to select the best protocol features considering network property and performance requirements.
3) How to test the usage of the dataset to be useful for future research comparisons.

The main aim of this research is to present a novel framework for performance analysis and adoption of MANET routing protocols. The framework consists of three integrated main phases; the first phase starts by investigating the performance of all MANET routing protocols' categories. The second phase uses the outcome of the first phase to build an evaluation dataset ready for applying machine learning techniques to predicate the performance behavior of each routing protocol.

The last phase allows the adoption of optimal MANET protocol within different network scenarios, and considering performance needs.

1) Understand MANET routing protocols through literature, and determine list of protocols categories to be investigating.
2) Analyze selected protocols' performance in different network scenarios.
3) Build a dataset used for estimating and predicting routing protocols performance within different network scenarios.
4) Allow the adoption of optimal protocol features based on network properties and settings.

II. LITERATURE REVIEWS

MANET is an autonomous network. MANET is represented by a group of wireless mobile nodes that dynamically creates the network without fixed physical infrastructure or centralized access point. In MANETs, the nodes are interconnected using multi-hop and communication paths that are used to forwarding the data packets from source node to destination (Goswami, et al., 2017), as shown in figure (2).

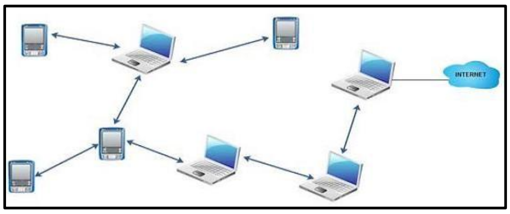

Figure 2: A Simple Mobile Ad Hoc Network (MANET)

The nodes that are within the radio range easily communicate with each other. However, the nodes that are outside the range need intermediate nodes to route their data packets over the network.

MANETs plays an essential role in finding and maintaining the routes with the help of routers. Routing in MANETs is one of the main challenges affecting its performance. Routing in MANET is considered as a complex task due to the mobility of nodes and unstable topology. In addition, each node works as a router and user simultaneously. Moreover, the routing information must be updated periodically M.,Z.,&H.(2016).Many routing algorithms are suggested for MANET to ensure the delivery of data packets to the destinations nodes safely. Also, many MANET routing categories have been used to reduce routing problems Sharma & Kaur (2016).

There are many challenges faced by MANET routing protocols Purohit & Keswani (2017), such as:

1) **Security:** The wireless medium in the nature of MANETs is considered as a vulnerable that may lead to drop packets and exposed too many security attacks.
2) **Quality of Service:** It is essential to maintain the best quality of service due to the dynamic changes in the MANETs topology, progression of the mobile technology and multimedia.
3) **Routing Overhead:** The topology of the MANETs is always changed due to the movement of the nodes within network, which leads to overhead in the routing table.
4) **Inter-Networking:** It is represented the communication inside the MANET and the communication between MANET and fixed networks.
5) **Power Consumption:** The communication between the nodes consumes power. Therefore, the power needed for routing must be optimized in the mobile ad hoc network.
6) **Location-aided Routing:** Location-aided routing defines the nodes regions using positioning information that lead to limited broadcast in the mobile ad hoc network.
7) **Scalability:** The network provides a specific level of service to communicate a large number of nodes with another using the ad-hoc routing protocol.
8) **Packet Losses:** The wireless medium in the nature of MANETs leads to loss data packets due to transmission errors, increased collisions, interference, path breaks due to movement of nodes.

ISSN (online): 2581-3048
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There are many applications utilizing MANETs in several fields commercial, Military and private sectors Raza, et al. (2016).

1) **Military Battle Field:** The military benefits from the mobile Ad-Hoc network exchange the information between the soldiers in different positions, vehicles, and military head.
2) **Local Level:** The mobile Ad-Hoc network provides easy used of the notebook computers to share information in conference or classroom among participants.
3) **Personal Area Network and Bluetooth:** There are a short-range MANET used to localized network with a given person such as Bluetooth through their laptop and mobile phone.
4) **Commercial Sector:** The mobile Ad-Hoc network is more useful in the emergency operations such as in fire, flood, or earthquake. Specially, when there is no damaged communications infrastructure.

The performance of MANET routing protocols can be evaluated based on the following matrices:

2.1 Packet Delivery Ratio (PDR)

Packet delivery ratio (PDR) is the ratio of data packets delivered in success manner to destination nodes over the total number of data packets created for those destinations nodes. PDR identifies the packet loss rate and network throughput. The decent performance of the routing protocol based on the high delivery ratio Bhatia & Verma (2015). PDR is denoted as:

$$PDR = \frac{\text{Total number of successfully deliverd packets}}{\text{Total number of transmitted packets}} \qquad (1)$$

2.2 Throughput (THP)

Throughput is the ratio of total data reaches to the receiver from the sender, considering the time required to receive the last packet. Throughput is measured by bytes or bits per second. There are many factors may affect the throughput such as topology changes, limited bandwidth, unreliable communication between nodes and limited energy Sisodia, et al. (2017). Throughput is represented as:

$$THP\ (kbps) = \frac{\text{packet size} * \text{receive} * 8.0}{1000 * (\text{end}_{time} - \text{start}_{time})} \qquad (2)$$

2.3 Routing Overhead (RO)

Routing overhead is the ratio of routing-related transmissions packets (RREQ, RREP and RERR that are generated by routing protocol) to data packets transmissions in mobile ad hoc networks. All the data packets forwarded through the network layer are consider as routing overhead Goswami, et al., (2017). The routing overhead is denoted mathematically as:

$$RO = \frac{\sum \text{Routing packets}}{\sum \text{Packets received}} \qquad (3)$$

2.4 End-to-End Delay (E2EDelay)

The End-to-End delay is the time taken to transmit a data packet across a MANET from source node to destination node. The End-to-End delay includes the propagation and the transfer time of data packets as well as delays like buffering, waiting in the queue, retransmission time. The average end-to-end delay is calculated as the total times taken by all received packets divided by their total numbers. The better the performance, the lower the End-to-End Delay value Sisodia, et al.(2017).

$$E2E\ Delay = \sum_{Packet\ id = 1}^{N} \frac{Received_{packetid} - Sent_{packetid}}{N} \qquad (4)$$

2.5 Routing in MANET

The absence of fixed infrastructure in a MANET poses several types of challenges. The most challenge among them is routing. Routing is the process of selecting paths in a network along which to send data packets. An ad hoc routing protocol is a convention, or standard, that controls how nodes decide which way to route packets between computing devices in a mobile ad-hoc network. In MANETs, nodes do not start out familiar with the topology of their networks, while, they have to discover it. The basic idea is that a new node may announce its presence and should listen for announcements broadcast by its neighbors. Each node learns about nearby nodes and how to reach them and may announce that it can reach them too. The routing process usually directs forwarding on the basis of routing tables which maintain a record of the routes to various network destinations. Thus, constructing routing tables, which are held in the router's memory, is very important for efficient routing. Lee, F. (2011).

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

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2.6 Classification of MANET Routing Protocols

MANET routing protocols can be divided into two main categories: Topology-based protocols and Position-based protocols varshney, et al. (2016).

2.6.1 Topology-Based Routing Protocols

The Topology-Based Routing Protocols uses the existing links information that are available in the network to propagate data packets Purohit & Keswani (2017). Topology-based routing protocols depend on the current topology of the network and cope with the dynamic nature of MANET. The topology-based routing protocols have limited performance while being comparing with geographical (position based) routing protocols, which use additional information in order to determine the node location. Topology-Based Routing model generally requires additional node topology information during the routing decision process, and are divided into; proactive routing protocols(table-driven), reactive routing protocols(table-driven), and Hybrid routing protocols Mahmood & Manivannan (2015).

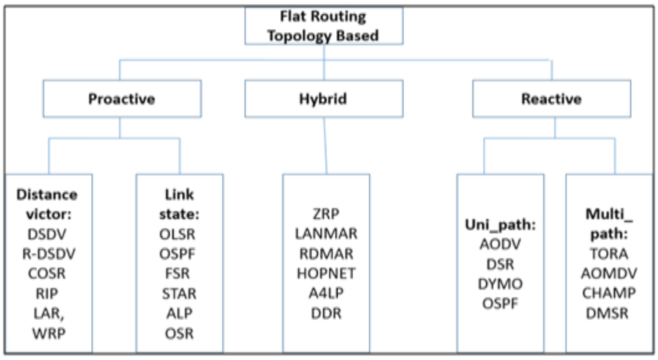

Figure 3: Classification of Topology Based Routing Protocols in MANET Ahmed & Khalifa (2017)

2.6.2 The Proactive Protocols (Table-Driven)

The network is under constant survey in order to know all possible routes between nodes at any given time. This means that routes are constantly being discovered, even if routes have not been invalidated. Exchange table for each node, which contains the latest information of routes to nodes, to know its local neighborhood. This control messages are continuously exchanged. Examples of proactive protocols are Destination-Sequenced Distance Vector (DSDV), Optimized Link-State Routing (OLSR), Topology-Based Reverse Path Forwarding (TBRPF) Protocols, and Core-Extraction Distributed Ad hoc Routing (CEDAR). Proactive routing protocols consist of two types based on its operational algorithm distance vector and link state:Ahmed & Khalifa(2017).

2.6.2.1 Distance-Vector Routing Protocols

Distant vector protocol is also known as Distributed Bellman-Ford or RIP (Routing Information Protocol). In a distance vector routing protocol, every host keeps a routing table containing the distances from itself to possible destinations, or it holds details of next hope node and number of hops to reach the destination. In other words, each routing table entry contains the next hop to the destination and the distance to the destination. The distance metric might be the number of hops, the delay, the quality of links along the path, etc. The chosen next hops are based on the shortest path to the destination Jagdale at el.(2012).

2.6.2.2 Destination-Sequenced Distance-Vector Routing (DSDV)

DSDV is an example of distance vector classification. Where DSDV is a proactive routing protocol that uses distance vector routing and sequence number produced by the destination to solve the routing loop problem. The routing tables contain the information of hop counts required to reach the various destinations. The routing tables are updated periodically Raju &Reddy (2017).

2.6.3 Link State Routing Protocols

In link-state protocols, a router does not provide the information about the destination instead it provides the information about the topology of the network. This usually consists of the network segments and links that are attached to that particular router along with the state of the link i.e., whether the link is in active state or the inactive state. This information is flooded through the network and then every router in the network builds its own picture of the current state of all the links in the network. OSLR is an example of link state category.

2.6.3.1 Optimized Link State Routing (OLSR)

OLSR is a proactive protocol. OLSR works on reducing the retransmission in the same area. The network nodes exchange HELLO messages with neighbors to update the routing information. Each node selects group of nodes as multipoint relays (MPR) to sends the topological information to them through MPRs selectors Raju & Reddy (2017).

2.6.3.2 The Reactive Protocols (On Demand)

This type of protocol attempts to create paths between nodes only when needed or when paths are not valid. Thus, interactive routing protocols such as AODV try to create a path to a destination when needed only. Discover only roads based on demand and do not take the initiative to find the way. Interactive routing requires less memory and storage capacity

ISSN (online): 2581-3048
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than proactive protocols. Do not update the path tables constantly. The reaction protocol is also known. As the on-demand routing protocol that does not maintain routing information or routing activity in the network nodes that do not have a connection. In this protocol, you want the node to send a packet to the other node while for the route in a customized way and create a way connection to send and receive the packet in a manner. Packages will be routed over the network by flooding the road caused by road discovery. Examples of reactive or on- demand routing protocols are: AODV, DYMO, TORA, AQOR, ARA Ahmed & Khalifa, (2017). Reactive routing protocols are divided into Uni-path routing and multi path routing protocols.

2.6.4 Uni-Path Routing Protocols

Even if several equally good paths are available, the uni-path routing protocols use only one path at a time to a given destination. Such protocols as AODV, OSPF, DSR, and DYMO operate with this strategy. Most routing protocols are unipath or have a unipath mode of operation. A commonly used routing protocol called Open Shortest Path First (OSPF) operates in a unipath mode equal-cost multipath routing is enabled or turned on in the protocol. Route discovery and route maintenance are the two steps followed by each protocol. Route discovery: Source node first finds a route or several routes to the destination, when it needs to send packets to a destination. This process is called route discovery. Route maintenance: The source transmits packets with the route. The route may be broken during the transmission of packets, because the node on the route move away or godown.Thebrokenroutewillbereconstructed.Theprocessofdetectingroutebreakage and rebuilding the route is called route maintenance Ahmed & Khalifa (2017). DSR and AODV are examples of uni-path routing:

2.6.4.1 Destination Sequence Routing (DSR)

DSR is a reactive routing protocol. The DSR uses two techniques to discover and maintenance the route. When the source sends packets to the destination, full path is generated. The path is created through flooding the network with route requests (RREQ) and then the nodes reply by sending route reply (RREP) that unicasting to the source. Lastly, the route updated through the stored information in the data packet Hong & Gerla (2002).

2.6.4.2 Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV is a reactive routing protocol. The AODV uses DSR techniques to discover and maintenance route. The source node sends (RREQs) that floods to their neighbors, then (RREP) is sent back to the source to identify the path of the destination Ahmed & Khalifa (2017).

2.6.5 Multi-Path Routing

In single path routing protocols, a single route is discovered between source and destination. Multipath routing does discovery of multiple routes between source and destination in single route discovery. Multipath Routing is the process of distributing the data from the source node to the destination node over multiple paths. Multipath algorithms permit traffic multiplexing over multiple paths. Multipath Routing performs better by proper usage of network resources. This category provides better throughput and reliability than single path protocols. The main goals of multipath routing protocols are to maintain reliable communication, to reduce routing overhead by use of secondary paths, to ensure load balancing, to improve quality of service, to avoid the additional route discovery overhead Kukreja & Kambhra (2014). TORA is an example of multipath routing:

2.6.5.1 Temporally Ordered Routing Algorithm (TORA)

TORA is a source-initiated on-demand routing protocol, which uses a link reversal algorithm and provides loop-free multipath routes to a destination node. In TORA, each node maintains its one-hop local topology information and also has the capability to detect partitions. TORA is proposed to operate in a highly dynamic mobile networking environment. The key design concept of TORA is the location of control messages sent to a very small set of nodes near the occurrence of a topological change. The protocol performs three basic functions: (1) route creation, (2) route maintenance, and (3) route erasure Kukreja & Kambhra (2014).

2.6.6 The Hybrid Routing Protocols

This major category represents a combination of reactive and proactive routing protocols. These protocols have the advantage of both proactive and reactive routing protocols to balance the delay which was the disadvantage of table driven protocols and control overhead (in terms of control packages) in on-demand routing. Main feature of Hybrid Routing protocol is that the routing is proactive for short distances and reactive for long distances Examples of these categories are: ZRP, LANMAR, HOPNET, and DDR.

2.6.6.1 Zone Routing Protocol (ZRP)

ZRP is a hybrid protocol that gathers the advantages of both proactive and reactive routing protocols. The ZRP routing protocol has three units known as, Interzone Routing Protocol (IERP), Intrazone zone routing protocol (IARP) and Border cast Resolution Protocol (BRP).Each unit works

ISSN (online): 2581-3048
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autonomously from the other ones. IARP is used inside the zone. The nodes inside the zone work in proactive manner. When the destination node is not available inside the zone, the IERP is used. The IERP based on BRP that search for the nodes outside the source node zone (Sisodia, et al., 2017).

2.6.7 Position-Based Routing Protocols

The Position-Based Routing Protocols depend on the position of mobile nodes in the network. The Position-Based Routing Protocols are represented by Greedy Forwarding, Restricted directional flooding, Hierarchical and Location based routing Protocols Raju, et al.(2017).

2.6.7.1 Greedy Forwarding Routing Protocols

In the Greedy Forwarding Routing Protocols, the local topology must be updated to maintain the network. Therefore, all the nodes broadcast a small data packet called beacon contains their position. Thus, each node sends the data packet to its neighboring node, which is nearer to the destination and each in between node do the same thing to reaches the destination. The disadvantage of these protocols is the congestion in the network that may generate. In addition, the computations at the nodes increase the delay at each node Wang & Liang (2012).

2.6.7.2 Greedy Perimeter Stateless Routing (GPSR)

(GPSR) is one of the routing protocols that used in a wireless sensor network which makes a packet forwarding decision depend on the positions of routers and a packet's destination. The base algorithm for this protocol is the greedy algorithm which used to establish the route (Wang & Liang, 2012). It uses two schemes: greedy forwarding scheme and perimeter forwarding scheme in the route process. The forwarding process using the greedy scheme to choose the next forwarding node which is the nearest to the destination than any other node. To avoid the local maximum problem that could happen in the greedy scheme, the routing protocol suggests the perimeter forwarding scheme, which forwards the packet by the right-hand rule. It needs a geographical information for the nodes that can be got through Global Positioning System (GPS) or other location services Hu et al.(2012)Shanthi &Anita (2017).

In every protocol, there were some disadvantages and here there were some drawbacks in the GPSR algorithm, mention some of them Wang & Liang, (2012):

1) Using a single path will increase the possibility of losing the node its energy.
2) The perimeter forwarding path has no evidence that it's the best path for the routing choice and it could be very long.

2.7 Related works

As shown in table 1, in terms of packet delivery ratio and order protocols performance according to network settings, the AODV provide the best achievement in low dense environment while the DSR is better in packet delivery ratio when the size of the network increases.

In the throughput the AODV is the best then, the DSR, OLSR, DSDV and ZRP is the worst. While in the routing overhead term the DSR perform better when the numbers of nodes are less but it will fail when the numbers of nodes increase. In the E2ED the AODV and DSR are provided the best performance while the TORA is the worst in conclusion, AODV provides best performance requirement and DSR after AODV. Although, The ZRP can be more effectively used by selecting wide zone. TORA is very poor and not reliable for the MANETs. Finally, we can extract the drawbacks and limitations in the previous studies as follows:

1) The lack of generalized analysis model used to investigate the performance of routing protocols allowing for protocols capability adaptation with network properties.
2) The scattered and undefined performance evaluation work leading to unclear pathway of protocols performance development.

TABLE 1
Related Work Analysis Summary

Related paper	Protocols	Network parameters	Metrics	Result
Safdar, et al., (2016	AODV, DSR and DSDV	Number of node: 50,100 Node speed: 5,15,30 Area: 1000x1000ms 2.	End to End Delay, Throughput and Packet	- AODV is best in average throughput - DSR is best in throughput - DSDV better in average throughput - OLSR is best in terms of end-to-end delay with respect to the mobility speed.

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Mohamed, el al., (2016)	DSDV, AODV and DSR	Number of node: 20,40,60,80 Node speed:10, 20,30,40, 50 Area:1000x1000, 2000x2000, 3000x3000, 4000x4000	Throughput	- In DSDV, the load increases and the throughput increases slowly but less than AODV and DSR - In the DSR, when the load increases, the throughput increases.
Al-khatib &Hassan(2017)	AODV, DSR, and DSDV	Number of node: 10,20,30,40,50 Node speed:- Area:1000x800	Throughput, E2E Delay and Packet Loss Rate	- AODV, DSR, and DSDV protocols provide different E2E delay results based on number of nodes. - The AODV and DSR throughput performance are almost the same.
Sharma & Kaur (2016)	OLSR and TORA	Number of node: 10,20,30,40,50 Node speed:- Area:1000x800	E2E delay, network load and throughput	- TORA E2E delay is higher than the OLSR. - The load of OLSR is higher than TORA. - OLSR shows the largest throughput
Varshney, et al., (2016)	OLSR and STAR	Number of node: 10,20,30,40,50 Node speed:50ms Area: 500 X 500	jitter, E2E delay, throughput	- OLSR performance is better than STAR with increasing the number of node.
Goswami, et al., (2017)	AODV, DSR, and DSDV	Number of node: 100 Node speed: 3,10, 25, 50ms Area: -500 X 500	PDR, routing overhead, throughput	- AODV provided a lower packet loss and delay with higher throughput compared withothers.
Bai & Wang (2017)	DSDV, FSR, AODV, DSR, TORA	Number of node: 5, 10 ,30 Node speed:10ms Area: 500 X 500	Routing overhead, E2E delay and throughput	- DSR is better in packet delivery ratio. The reactive protocols become the best when the size of the network increases.
Bhatia& Verma (2015)	AODV, DSR, DSDV, OLSR, ZRP	Number of node20, 40, 60, 80, 100Node speed: 5, 10, 20,30,50 ms Area: 500 X 500	Throughput, packet delivery and average E2E delay	-The AODV is the best then, the DSR, OLSR, DSDV and ZRP is the worst. -AODV and DSR perform better than DSDV in high mobility scenarios -ZRP can be more effectively used by selecting optimum zone radius.
Pawar, ET AL.,(2017)	AODV,DSDV, DSR, OLSR, TORA	Number of node: 25,50,75,100 Node speed:20ms Area: 700x700	PDR, E2ED, RO, Throughput	- The delay of OLSR is less and in theDSR is worst - Throughput is high in case of AODV - DSR delay is greater than the AODV and OLSR - TORA is very poor and not reliable for the MANETs
Chaubey, et al., (2015)	TSDRP and AODV	Number of node: 10,20,30,40,50,60,70 Node speed: 100ms Area: 1000x1000	PDR, AED, AT and NRL.	- The TSDRP is better than the AODV
Katiyar, et al.,	AODV,O	Number of	PDR, E2E	AODV is more suitable for military

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(2015)	LSR	node: 50,75 Node speed:4ms Area: 1000x1000m	delay, Average Overhead	application then OLSR

III. METHODOLOGY

Figure 4 shows the overall research design, which represents the general overview of this thesis framework.

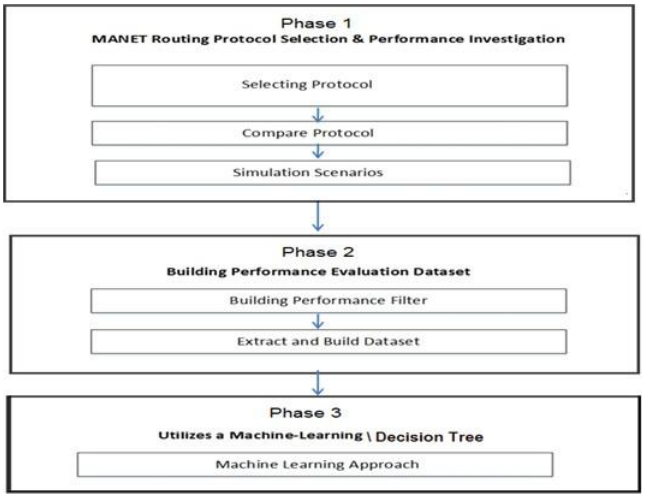

Figure 4: Proposed Performance Analysis Framework

The proposed framework consists of three integrated main phases:

1) The first phase starts by investigating the performance of all MANET routing protocols' categories including: proactive, reactive, and hybrid classification. The following protocols were selected for evaluation: DSDV, OLSR, AODV, DSR, TORA, ZRP and GPSR. The protocols where selected based on comparative analysis conducted on literature review. This investigation study is conducted using a simulation environment built using network simulator (NS-2). In which a number of simulation scenarios were designed implementing different network parameters and settings.
2) The second phase uses the outcome of the first phase to build an evaluation dataset ready for applying machine learning techniques to predicate the performance behavior of each routing protocol. This dataset is built based on implementing a filter to deduce best and worst protocols practices within networks parameters as reported by simulation work conducted in the first phase.
3) The final phase utilizes a machine-learning model, built using MATLAB module (using decision tree approach) to allow the definition of networks properties in order to decide most optimal protocol or decide best protocol features. The last phase allows the adoption of optimal MANET protocol within different network scenarios, and considering performance needs.

3.1 Phase1: MANET Routing Protocol Selection and Performance Investigation

3.1.1 Selecting Protocol According to Classification

In the first step of phase1, select protocols according to the different of its classifications and methodologies. Protocols may be described in terms of the state information obtained at each node and / or exchanged among nodes. Topology-based protocols use the principle that every node in a network maintains large-scale topology information. This principle is just the same as link-state protocols use. The way to obtain route information can be a continuous or a regular procedure or it can be trigged only by on demand. On that basis the protocols can be classified to proactive and on-demand (reactive) protocols. Another hand, the Hybrid protocol uses advantages of proactive and reactive protocols to balance the delay and ignored the disadvantage of both classifications which the main aim of it that routing is proactive for short distances and reactive for long distances. Thus, this thesis selected the form topology-based classification. Then GPSR protocol selected from position-based routing protocols as an example of greedy forwarding routing protocols.

3.1.2 Compare Protocol According to Literature Review

In the second step of phase1, literature survey conducted around MANET routing protocols with different properties and performance parameters is used to select the appropriate protocols and the network parameters that are used in this study. Taking into consideration the most popular one of the protocols on each category that are referred in the previous chapter table 2.1. As mentioned shown in table 2 below:

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ISSN (online): 2581-3048
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TABLE 2
Selected Protocols Category and Protocol Method

Protocol	Category	Protocol method
DSDV	Topology-based \ proactive	Distance-Vector Routing Protocol
OLSR	Topology-based \ proactive	Link State Routing Protocol
AODV	Topology-based \reactive	Uni-path Routing Protocol
DSR	Topology-based \ reactive	Uni-Path Routing Protocol
TORA	Topology-based \ reactive	Multi-path Routing Protocol
ZRP	Topology-based \ hybrid	Combination proactive and reactive
GPSR	Position-based	Greedy forwarding routing protocol

3.1.3 Implementing selected MANET Routing Protocols: Simulation Scenarios

In the final step of phase1, selected protocols were implemented and evaluated in NS-2 simulation. The implantation is conducted using different scenarios representing different values of the following three of variables:

1) Number of node
2) Node speed m/s
3) Number of connection

The 3 table below presents an example of used variables for each network scenario. Where the values of the variable selected based on the related works in terms of selection of a random group from the minimum of minimum and the maximum of maximum of each value in the related works:

TABLE 3
Varying Networks Properties

Number of node	10,40,60,80,100
node speed m/s	5,10,25,40,60
number of connection	Six random number depend on number of node

The scenarios of the implementing selected protocols are:

3.1.4 Scenario 1: The environment setting of scenario1 consisted of constant of number of node as shown the values in table 3.2. In addition, five varying values of speed in addition to six different number of connection depends on the value of number of node were selected.

Scenario 2: The environment setting of scenario 2 consisted of constant of speed of node as shown the values in table 3.2. In addition, five varying values of number of node in addition to six different number of connection depend on the value of number of node.

On each network scenarios protocols implementation, trace files for each protocol from NS- 2 simulation is produced. This trace file is used to calculate metrics to build the required dataset, which considers different protocols capabilities and network properties.

The evaluation work is based on the following performance metrics:

1) Average end to end delay (E2ED)
2) Packet Delivery Ratio (PDR)
3) Throughput (THP)
4) Routing Overhead (RO)

3.2 Phase 2: Building Performance Evaluation Dataset

The outcome of the previous phase used to build the performance evaluation of primary proposed data set which is consists of the protocols was selected, the networks parameters are used in all scenarios and the metrics were calculated. The table 4 has shown the sample of primary data set for different networks scenarios:

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TABLE 4
Sample of Primary Dataset for Different Networks Scenarios

Protocol	Node	speed	Connection	Packet Delivery Ratio	End to End Delay	Throughput (kbps)	Routing overhead
ZRP	10	5	2	0.555556	0.0561119	1.02	1.8
ZRP	100	5	150	0.22094	8.1841342	7.49	4.5261194
OLSR	10	25	2	0.40625	0.0127701	0.72	2.4615385
OLSR	10	60	8	0.190476	1.4812572	1.02	5.25
GPSR	10	40	2	0.485714	0.00001	1.01	2.0588235
GPSR	60	40	20	0.049223	0.00012	0.55	20.315789
DSR	10	10	2	0.2580645	6.4015133	0.5698159	3.875
DSR	10	10	15	0.3005181	3.8270652	1.5740227	3.3275862
DSDV	60	10	180	0.499299	0.1995798	9.89	2.002
DSDV	10	5	22	0.421348	0.1067129	2.12	2.3733333
AODV	10	25	30	0.759358	0.7319908	3.96	1.3169014
AODV	60	25	250	0.828452	0.0898987	16.52	1.2070707
TORA	10	5	15	0.229508	2.7920773	1.19	4.3571429
TORA	10	25	45	0.641711	4.5875582	3.34	1.5583333

3.3 Building Performance Filter

In this phase, after building the raw dataset according to the phase1 results. The results of metrics have shown the more same result in the different cases of scenarios. This is wrong for evaluation dataset to avoid this error need to build performance filter to prepare the data to be a good and real experiment data on the proposed dataset and ready to use in the next phase. Appears that the cause of repetition in the results is increased of number of connection in the different scenarios much larger than the number of node as shown in table 5 below.

TABLE 5
Sample of Repetition Result in Raw Dataset

Protocol	Node	speed	Connection	PDR	E2ED	THP
ZRP	10	5	8	0.619048	1.7527282	3.3
ZRP	10	5	20	0.619048	1.7527282	3.3
ZRP	10	5	35	0.619048	1.7527282	3.3
ZRP	10	5	38	0.619048	1.7527282	3.3
ZRP	10	5	40	0.619048	1.7527282	3.3
ZRP	10	5	45	0.619048	1.7527282	3.3

The figures 5 below show the performance filter process:

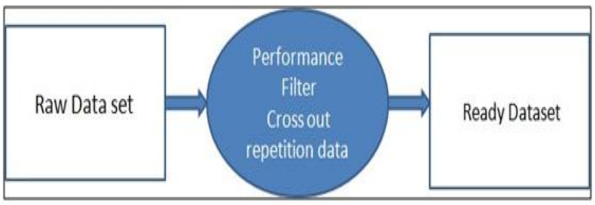

Figure 5: Performance Filter Process

Performance filter does the following steps:

1) Collect the repetition that has same scenarios number of node and node speed.
2) Get the average of the maximum and the minimum number of connection to the repetition row.
3) Get one of the repetition rows and cross out another with the new value of the number of connection set it the average where was calculated in the previous step.

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According to the table 6, after applying the performance filter the final dataset is combined to the domain as is shown in table 3.5:

TABLE 6
Sample of Result after Performance Filter

Protocol	Node	speed	Connection	PDR	E2ED	THP
ZRP	10	5	8	0.619048	1.7527282	3.3

3.4 Build Dataset

Finally, in this step, uses the outcome of the pervious step to build an evaluation dataset ready for applying machine learning techniques to predicate the performance behavior of each routing protocol. By collecting the performance filter result as it is in one file.

3.5 Using Machine Learning Approach for Scenarios Testing

Machine learning is a branch of artificial intelligence, its considered as a parameter for intelligent machines Talwar & Kumar, (2012), that allows computer systems to learn directly from examples, data, and experience, it has been making great progress in many directions.

In this phase, a machine learning approach was developed using Matlab. Decision tree approach is used, which it's one of the most important classification measures in data mining.Anddecisiontreesarepowerfulandpopulartoolsforclassification, decision trees represent rules, which can be understood by humans and used in knowledge system such as database. Generally, decision tree used as a decision support system. It is used to classify a record to find a path that from root to leaf by measuring the attributes test, and the attribute on the leaf is classification result Dai, Zhang, & Wu,(2016). A set of testing scenarios are defined to be used by machine learning module.

Machine learning module uses input variables (number of nodes, connection, and speed) as well as performance requirement (PDR, E2ED, THP, and RO). Afterward, the machine learning is working to determine the most appropriate protocols according to the input values of features factor. Which is the feature vector being the values using to determine the class where the class is a protocol shown in figure 6.

Protocol	Node	Speed	Connection	PDR	E2ED	THP	RO

Figure 6: Machine Learning Feature Factor

3.6 Simulation Tools &Settings

Research tools that will be used in this research are the followed:

1) NS2: for the implementation of protocols.
2) Matlab: for building machine learning.
3) Hardware and Software Specifications.

The used materials as shown in the table below, which used to run experiments:

TABLE 7
Used Materials

Material	Details
Laptop specifications	ThinkPad Yoga, RAM: 8 G , Processor Intel(R) Core(TM) i5-6200U
OS	Ubuntu 16.04.4 LTS (Xenial Xerus) 64-bit PC (AMD64)
Simulator	NS version 2.35

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The Programming Language	TCL using NS2 simulator
Routing Protocols	DSDV, OLSR, AODV, DSR, TORA, ZRP, GPSR
Simulation time	150 s
Simulation area	600 m* 600 m
Mobility model	Random waypoint
Minimum speed	0 m/s
Maximum speed	10 m/s
Data packet size	512 bytes
Transmission range	250 m

The table 8 below explains the all-possible simulation scenarios parameters while changing a number of nodes and node speed after filter the dataset:

TABLE 8
Simulation Scenarios Parameters after filter

	Type CBR - TCP	Number of nodes	Seed	Maximum connections
1	CBR	10	5,10,25,45,60	2,8
2	CBR	40	5,10,25,45,60	20,100
3	CBR	60	5,10,25,45,60	60,100
4	CBR	80	5,10,25,45,60	200
5	CBR	100	5,10,25,45,60	300

IV. RESULT AND ANALYSIS

4.1 Protocols Performance Comparison

According to build performance evaluation dataset phase, especially in extract and build dataset phase, we are going to compare the results for each protocol. The input values (initial values) for each protocol was the number of nodes, number of speed, and number of connections. The output from trace files for each scenario as the following bellow metrics:

4.1.1 The Average of Packet Delivery Ratio

Figure 7, shown the average of packet delivery ratio (PDR) for all protocols. Where the DSR protocol has the maximum average of PDR value between all protocols, the average for DSR reached to 0.799. While GPSR protocol has the minimum average of PDR value, it’s reached to 0.08.

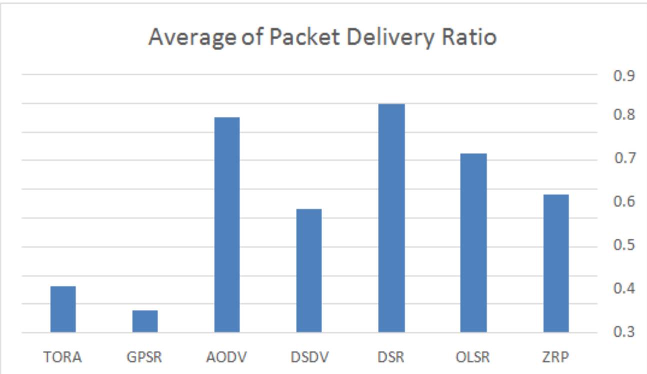

Figure 7: The Average of Packet Delivery Ratio

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4.1.2 The Average of End-to-End Delay between Nodes

TORA protocol has the maximum average of end-to-end delay between nodes, as it shown in figure 8 the average of delay for TORA protocol was reached to 2.937.

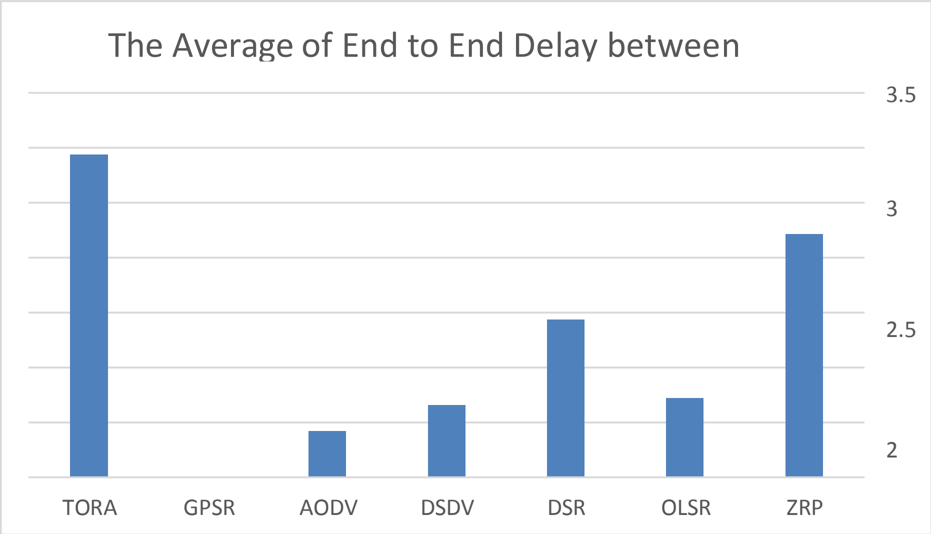

Figure 8: The Average of End to End Delay between Nodes

While GPSR protocol has the minimum average of end to end delay between nodes, where it reached to 0.00013.

4.1.3 The Average of Throughput

AODV and DSR protocols have the maximum average of throughput, as it shown in figure 9, where AODV reached to 12.67, and DSR reached to 12.68.

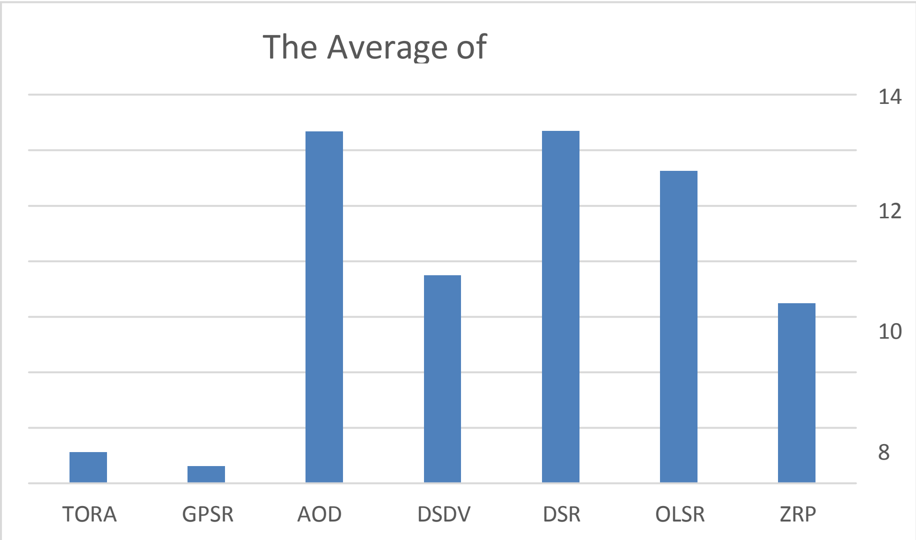

Figure 9: The Average of Throughput

While GPSR protocol has the minimum average of throughput between nodes, where it reached to 0.615.

4.1.4 Routing Overhead

AODV and DSR protocols have the maximum average of routing overhead, as it shown in figure 10, where AODV reached to 4.186, and DSR reached to 9.568.

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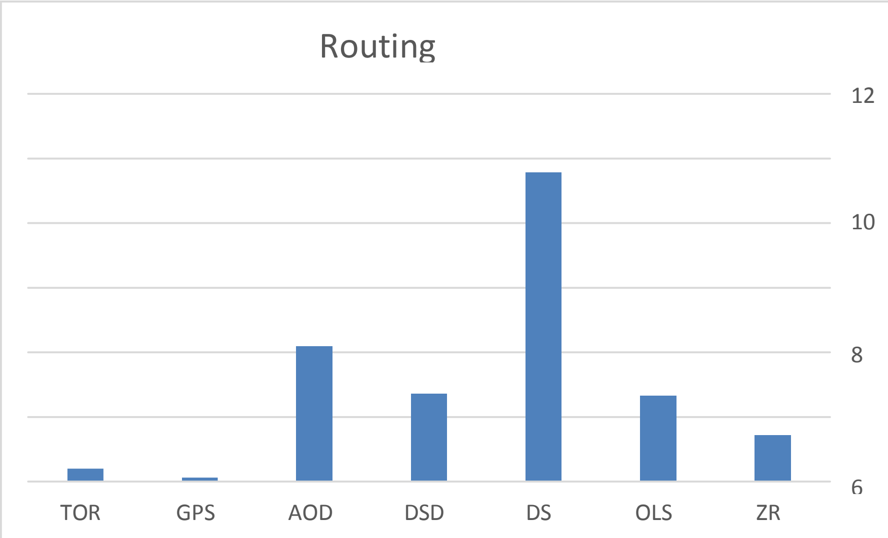

Figure 10: The Average of Routing Overhead

While GPSR protocol has the minimum average of throughput between nodes, where it reached to 0.123.

4.2 Results according proposed model scenarios

4.2.1 Scenario 1

In this scenario, the environment setting consists of constant of number of node which are (10, 40, 60, 80,100) node. And five varying values of speed within (5,10,25,40,60)ms. In addition to two different number of the connection depends on the value of number of node was selected. The table 9 shows the result of average the networks requirement according to fixed number of node with varying speed and varying number of connection.

TABLE 9

Result of average the networks requirement according to fixed number of node

Protocol	Performance metrics	10 nodes	40 nodes	60 nodes	80 nodes	100 nodes
ZRP	PDR	0.51209	0.622001	0.191945	0.330151	0.116779
	E2ED	2.635392	0.157605	0.577757	3.870234	7.878533
	THP	1.827	9.045	1.847255	8.228	3.94
	RO	2.352701	1.672507	9.002	4.454591	10.42653
OLSR	PDR	0.356462	0.701003	0.683546	0.693264	0.65312
	E2ED	0.2394762	0.359336	0.822888	1.417018	1.302156
	THP	1.283	10.21	1.526207	17.26667	21.702
	RO	3.702865	1.456533	10.645	1.547642	1.608309
DSR	PDR	0.671541	0.87894	0.864233	0.838731	0.725166
	E2ED	3.7494059	0.523378	0.441892	0.713497	1.325164
	THP	2.349076	12.58269	1.165533	20.56728	23.87602
	RO	1.773743	1.143933	13.60054	1.247511	1.602087
DSDV	PDR	0.281975	0.466345	0.490911	0.799254	0.518674
	E2ED	0.2023257	0.720357	0.507215	0.723994	0.916937
	THP	0.998889	6.685556	2.103115	19.67942	17.39
	RO	4.326927	2.246808	7.007778	1.299817	2.094065
AODV	PDR	0.516929	0.775213	0.763049	0.495932	0.791311
	E2ED	1.2045034	0.307237	0.215648	1.044293	0.175446

	THP	1.821	11.227	1.44592	12.192	26.474
	RO	2.502407	1.386808	11.892	2.204031	1.275025
GPSR	PDR	0.300799	0.162725	0.149094	0.022196	0.015936
	E2ED	0.0000001	0.5345	0.224593	2.6584	2.6584
	THP	0.768333	2.646667	3.816666	0.556	0.51
	RO	5.531046	4.135154	2.733333	2.300449	24.06797
TORA	PDR	0.437416	0.023517	0.123929	0.005256	0.00442
	E2ED	3.588534	1.330095	0.486009	2.142378	1.290958
	THP	1.635556	0.703333	0.486667	2.573333	1.128
	RO	2.923229	4.41152	4.416667	200.6667	488.63

4.2.2 Scenario 2

The environment setting of scenario2 consisted of constant of speed of node as shown the values in (5,10,25,40,60)ms. And five varying values of number of node. In addition, two different number of connection depends on the value of number of node.

Table 10
Result of average the networks requirement according to fixed node speed

protocol	Performance metrics	Speed 5ms	Speed 10ms	Speed 25ms	Speed 40ms	Speed 100ms
ZRP	PDR	0.667178	0.446302	0.50266	0.433226	0.369774
	E2ED	1.427971	1.807738	1.933089	2.825249	3.08011
	THP	9.80625	3.16603	5.9325	5.19875	4.4975
	RO	1.790474	7.0125	3.745055	3.824904	4.114814
OLSR	PDR	0.787541	0.607965	0.620167	0.531922	0.444692
	E2ED	0.094646	0.115542	0.634461	0.969889	1.834006
	THP	13.32875	2.817593	10.1175	8.95625	7.48
	RO	1.323825	11.49	1.659027	2.055453	2.527681
DSR	PDR	0.886438	1.481161	0.949904	1.936067	0.708206
	E2ED	0.421791	13.91778	13.45044	11.33842	2.378585
	THP	14.65702	1.71482	2.428971	6.1175	10.07878
	RO	1.162863	1.71482	1.175847	1.35521	1.476269
DSDV	PDR	0.604837	0.221155	0.622701	0.92076	0.30578
	E2ED	0.077962	8.11625	7.2325	6.1175	1.368803
	THP	9.9425	2.636726	1.175847	11.33842	5.175
	RO	1.737175	2.636726	2.428971	3.369293	3.440175
AODV	PDR	0.830091	0.458506	0.371171	0.54659	0.656475
	E2ED	0.096203	12.63	12.43625	11.90375	0.567479
	THP	13.96	2.306013	1.325008	10.79894	10.85375
	RO	1.246191	2.306013	1.325008	1.379812	1.582283
GPSR	PDR	0.099692	0.200222	0.998669	0.422144	0.101694
	E2ED	0.033416	0.6408	0.9958	0.71955	0.000143
	THP	0.62875	10.50849	27.71933	0.608571	0.62625
	RO	7.118414	30.50849	7.719331	8.057627	27.28189
TORA	PDR	1.310973	0.075	0.0825	0.8525	0.140497
	E2ED	1.46	58.5	112.625	49.5105	3.776231
	THP	11.96997	0.386667	1.173333	1.4	1.128333
	RO	2.969968	44.11111	129.5194	10.70983	148.4347

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Finally, table 11 shown the final results, which included of maximum and minimum average for each protocols, with each metrics.

TABLE 11
The Protocol Performance Comparison

	Maximum		Minimum	
	Max1	**Max2**	**Min1**	**Min2**
Packet Delivery Ratio	DSR	OADV	GPSR	TORA
End to End Delay	TORA	ZRP	GPSR	OADV
Throughput(kbps)	DSR	OADV	GPSR	TORA
Routing Overhead	DSR	OADV	GPSR	TORA

According to previous table, we can notice the results for each metric, we can notice also each of protocol DSR and AODV have the best results comparing with other protocols. In other hand, each of GPSR TORA has the worst results comparing with other protocols.

4.3 Testing Machine Learning Scenarios

This section will present the results of testing scenarios for the proposed dataset. The testing process is aims to identify the appropriate protocol for each scenario. In machine learning phase, the propose approach worked to select a random number as the input parameter for each scenario. Table 12 shown the testing scenarios:

TABLE 12
Testing Scenarios for Machine Learning Approach

	Nodes	Speed	Conn	Speed	Conn	Speed	Conn	Speed	Conn
Scenario 1	35	15	2	20	15	25	20	30	25
Scenario 2	45	20	2	20	8	20	20	20	40
Scenario 3	60	40	20	50	20	60	20	70	20
Scenario 4	20,60,70,100	50	20	50	150	50	200	50	150

The previous table shown the three scenarios for the testing machine-learning phase, each scenario has four different experiments. The implement for these scenarios using machine learning show the results in the table 13, which it is the selected protocol for each experiment.

TABLE 13
Selected Protocols for Machine Learning Approach

	Experiment	Node	Speed	Connection	Selected Protocol
Scenario 1	**Exp_1**	35	15	2	OADV
	Exp_2	35	20	15	DSR
	Exp_3	35	25	20	DSR
	Exp_4	35	30	25	DSDV
Scenario 2	**Exp_1**	45	20	2	OADV

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	Exp_2	45	20	8	OLSR
	Exp_3	45	20	20	DSR
	Exp_4	45	20	40	DSR
Scenario 3	**Exp_1**	60	40	20	OADV
	Exp_2	60	50	20	DSDV
	Exp_3	60	60	20	DSR
	Exp_4	60	70	20	GPSR
Scenario 4	**Exp_1**	20	50	20	DSR
	Exp_2	60	50	150	AODV
	Exp_3	70	50	200	TORA
	Exp_4	100	50	150	AODV

According to the previous table, show the percentage of accuracy for each experimenting the different scenarios in the table below:

TABLE 14
Percentage of Accuracy for All Experiment

	Accuracy
Scenario 1	83 %
Scenario 2	82%
Scenario 3	67%
Scenario 4	90%

Table 14, shown the accuracy for machine learning testing, the average off accuracy for all experiments are reaches to 81%.

V. CONCLUSION AND FUTURE WORKS

5.1 Conclusion

In this thesis, we worked to improve the performance for adapting the capabilities of routing protocols in MANET, And tried to reduce the random behavior for protocols in MANET through understating the properties in the network, and through understating the protocols' behaviors, and how its work.

ISSN (online): 2581-3048

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We built dataset to cover the most cases for protocols implementations, and then, tested it using machine learning and decision tree. The experiment results show the accuracy for machine learning reach to 81%. Finally, we can notice the best performance for each of DSR and AODV protocols comparing with other protocols according to average of all metrics in different scenarios will proposed. This means the reactive routing protocols achieves the best performance that hint to the reactive protocols have good features which it is can support uni-cast and multicast routing; it has lower setup delay for connection. The AODV adaptability to dynamic networks. The route is established only when it is required.

5.2 Limitation

The limitations in this work are as the following below:

1) The delay of protocols' implementation, where some of protocols need more than 10 hours for each case, such as TORA protocol.
2) The difficulty of getting patch files for the mostprotocols.
3) The limitation on NS-2 implementation for each of number of connection, and number of speed.

5.3 Future Work

In future work, we are looking to reach each of the following below:

1) Increase the cases of implementation for each protocol.
2) Enhance the accuracy for machine learning approach results.
3) Building dataset using more network simulations, like GLOMO simulation.
4) Building new protocol in MANET, and optimize it according to our understanding for protocol' behaviors.
5) Comparing the proposed protocol with others protocols.

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Citation of this Article:

Khawla Mohammed AlTarawneh, Asma'a Jameel Alnawaysih, "Toward an Improved Performance Analysis Model for Adapting the Capabilities of Routing Protocols in MANET" Published in *International Research Journal of Innovations in Engineering and Technology (IRJIET)*, Volume 3, Issue 9, pp 55-73, September 2019.

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